their lengths, and this part of the race is only wide enough to permit their respective rollers to work freely therein. In the remaining quarter of the length of the grooves or races they are enlarged, as at *a* and *b*, so as to give the rollers freedom to lift. When the pressure in the cylinders falls materially below that of the atmosphere during the exhaust, the valves 39 may open to admit air, after which they are again held shut by the cam grooves until the next period of exhaust is reached.

When small charges of the explosive mixture are employed, the pressure in the cylinders 6 and 7 quickly falls below that of the atmosphere during exhaust, and there is danger of the production of a partial vacuum in these cylinders, which would diminish the efficiency of the engine. To provide against such contingency, I place a valve 44 in the piston 12 of the low pressure cylinder, said valve being held normally against its seat by a spring 45. In case the pressure above the piston should become too low during exhaust this valve 44 opens and admits air through the piston into the cylinder. At such time, the valve 23 which controls the exhaust from the low pressure cylinder may also open backwardly and permit the exhausted gases to return to the low pressure cylinder.

All of the cylinders of the engine are provided with water jackets 46 to prevent them from becoming too hot, the water being preferably supplied to said jackets through the pipes 47, and being conducted from the cylinders through the pipes 48.

At 49, see Fig. 2, is shown a sparking device by which the charges in the high pressure cylinders may be ignited. Any suitable form of device of this character can be adopted and it is not deemed necessary to show or describe the same any more fully.

The piston 9 in the cylinder 6 is shown at the end of its intake stroke, and compression of the gases is ready to begin. The cam 29 has just passed the end of the rod 30, and the valve 16 has closed. As the piston moves upwardly to compress the gases in the cylinder 6, the piston 12 in the cylinder 8 moves downwardly, said latter cylinder receiving the exploded gases from cylinder 7, which is now exhausting, its piston moving upwardly in unison with the piston in cylinder 6. Consequently, the valve 20 between cylinders 7 and 8 must be opened at substantially the same instant that valve 16 on cylinder 6 closes, and the cams 29 and 33′ must be so placed as to effect this operation. Following the compression stroke of the piston in cylinder 6 comes the explosion in this cylinder, which drives the pistons in the high-pressure cylinders downward, and causes the piston 12 to rise. As the latter starts upwardly the main exhaust valve 23 is opened by its cam 36, and, at the same instant, the intake valve 16 for cylinder 7 opens. The cams for operating these valves must therefore, be so arranged as to open the valves at substantially the instant the piston in cylinder 6 starts on its explosion stroke. Following this stroke comes the upward stroke of exhaust, at the beginning of which the valve 20, between cylinders 6 and 8, must be opened by its cam 33 to permit the exploded gases to pass into the latter cylinder, the piston in which is driven downwardly thereby. The cylinder 8 being of much greater capacity than cylinder 6, the pressure in the latter rapidly falls until it drops below that of the atmosphere, when the air valve 39 opens to scavenge and cool the cylinder 6, the enlargement *a* in the cam race 40 having reached the roller on the rod 42 so as to permit of this operation. While the exhaust in cylinder 6 is taking place, the mixture in cylinder 7 is being compressed. At the completion of the exhaust, the piston in cylinder 6 starts on its intake stroke, at which instant valves 20 and 39 communicating with said cylinder must be closed and the valve 16 opened. The enlargement *a* in the cam race 40, must, therefore, have passed the roller on the rod 42, and said roller must have entered the narrow and concentric part of the cam-race. Also, the cam 33 must have passed the rod 34, and the cam 29 must have opened the valve 16. During the intake for cylinder 6 the piston in cylinder 7 is driven downwardly by the explosion therein, while the piston 12 moves upwardly to drive out the gases from cylinder 8, the main exhaust valve 23 having again opened to permit this operation. At the end of the intake movement of the piston in cylinder 6, the engine has completed its cycle of operation.

Having thus described my invention what I claim as new and desire to secure by Letters-Patent is:—

1. In a compound explosive engine, a high-pressure cylinder, a valve connected with said high-pressure cylinder through which air may be admitted thereto during the exhaust from the said cylinder, means for preventing said valve from opening except during the exhaust from the high-pressure cylinder, and a second valve through which the air is drawn from the cylinder, said air scavenging and cooling the cylinder.

2. In a compound explosive engine, a high-pressure cylinder, a low-pressure cylinder connected therewith, a valve connected with said high-pressure cylinder opposite the connections with the low-pressure cylinder through which air may be admitted into said cylinder during the exhaust therefrom, whereby the said cylinder is scavenged and cooled, a grooved cam, means for operating said cam, and connections from said cam to said valve whereby the latter is operated, the groove in the cam preventing the opening of